Relationship Between Environmental Parameters and Manta Ray Occurrence in Raja Ampat Archipelago, Indonesia

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Abstract

Understanding the influence and impact of environmental factors on manta ray sightings is critical to understanding the spatial and temporal ecology of a highly mobile species. Therefore, this study aims to determine the influence and impact of environmental factors as indicated by the parameters of wind speed, chlorophyll-a, SST, salinity, pH, dissolved oxygen, and the number of phytoplankton and zooplankton species. The mapped chlorophyll-a was re-analyzed based on the seasonal period throughout 2021 downloaded from marine copernicus and analyzed by kriging method. The influence and effects of environmental parameters on the short-term appearance of eye rays were studied using an adaptive model (GAM). The analysis showed a significant influence of environmental factors on manta ray sightings in Raja Ampat, namely Calanoid spp, Oithona nana, Acartia clausi, Calanus helgoladicus, and Oithona brevicornis. Based on this model, zooplankton is an important parameter that can describe the influence of environmental parameters on manta ray sightings at observation points in Raja Ampat MPA. The results of the reanalysis of chlorophyll-a concentrations were highest in the eastern to transitional seasons, which were scattered on the west side of Raja Ampat waters. Meanwhile, chlorophyll-a concentrations were low in the west to transitional season on the east side. This mechanism may drive the foraging strategy of manta rays, which visit shallow waters where zooplankton density and biomass are abundant. Adopting the BHS MPA network concept, as it has been implemented, would be in line with broader conservation expectations for the sustainability of manta rays in Raja Ampat.

Keywords: *Environment, GAMs, Hotspots, Parameters, Zooplankton*

Introduction

The geographical position of Raja Ampat waters acts as an Indonesian trough flow (ARLINDO), mixing water masses from the Pacific and Indian Oceans (Gordon, 2005). This mixing process results in relatively fertile waters favoured by various marine organisms. Manta rays are megafauna discovered in Raja Ampat and belong to the elasmobranch group known as filter feeders. They require a large amount of energy to support their life cycle (Burgess *et al*., 2016; Couturier *et al*., 2018). According to Setyawan *et al*. (2018), these species are of 2 types, namely reef manta rays (*Mobula alfredi,* Kreft 1868) and oceanic manta rays (*Mobula birostris*, Walbaum 1792) (Stewart *et al*., 2016; Beale *et al*., 2019). Furthermore, manta rays utilize Raja Ampat waters as a habitat for feeding, cleaning, and mating activities (Setyawan *et al*., 2020). One of the important areas for them is the feeding habitat which remains the most critical and preferred habitat.

Understanding the environmental linkages and distribution of megafauna species, such as manta rays, whale sharks, and leatherback, is crucial for supporting spatial and temporal ecological knowledge (Rohner *et al*., 2013). Spatial ecology studies have provided knowledge of the interrelationships between seascapes and the composition and distribution of organisms, populations, and communities. Temporal ecology explains the relationship between time and

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distribution as well as the dynamics of organisms and populations. In addition, ecological knowledge supports efforts to protect threatened species (Hsu *et al.*, 2022).

Previous studies have shown the loyal behaviour of the species towards feeding habitats, specifically in sites with increased zooplankton biomass and size (Armstrong *et al.*, 2021). As first-level consumers, zooplankton play a role in trophic levels and energy flow (Faiqoh *et al.*, 2015). It high abundance affects the appearance of manta rays (Couturier *et al.*, 2018; Armstrong *et al.*, 2021) and some elasmobranch species, including the ray devil (Lezama-Ochoa *et al.*, 2019), *D. coriacea*, *R.thypus* (Abdul *et al.*, 2020) and large pelagic such as *Thunnus* (Yamamoto S *et al.*, 2017). Several studies have examined the effect and influence of environmental factors on the appearance of manta rays in several areas. (Dewar *et al.*, 2008) and (Jaine *et al.*, 2012) monitored the movement and behaviour of the species in Indonesia and Australia based on factors such as sea surface temperature, wind, currents, and tides. (Anderson *et al.*, 2011) also examine the seasonal distribution of reef manta rays and their relationship with marine physical and biological processes. (Rohner *et al.*, 2013) estimated the trends in temporal occurrence and their relationship to the environment, distribution, and seasonality of sightings in Southern Mozambique. (Beale *et al.*, 2019) investigated the environmental factors related to the emergence of oceanic manta rays and the real influence of ENSO on the trend of sightings and possible changes in the regional distribution of oceanic manta rays in Raja Ampat waters. (Armstrong *et al.*, 2021) examined the influence of the tidal cycle on chlorophyll-a abundance and distribution, wind on zooplankton abundance, and their relationship with the distribution reef manta rays. The gap that needs to be addressed in detail is the relationship and influence between the sightings of manta rays in several habitats related to chlorophyll-a, zooplankton, and environmental factors at hotspots in Raja Ampat waters. This study should be continuously updated, considering that environmental variables can provide different interpretations, including sighting trend data (Rohner *et al.*, 2013).

This study provides an update on the relationship between environmental parameters and manta-ray aggregation. Some parameters used as references were salinity, temperature, pH, dissolved oxygen, wind speed, concentration, chlorophyll-a, and the number of zooplankton. To determine the spatial distribution of chlorophyll-a, data from marine Copernicus were re-analyzed using the kriging method in the ArcGIS software. Furthermore, the relationship and influence of chlorophyll-a, plankton abundance, and manta ray sightings were analyzed using Generalized Additive Models (GAMs), which describe the mechanism applied during the observation period. Therefore, this study aims to determine the influence and effect of environmental factors indicated by parameters such as wind speed, chlorophyll-a, sea surface temperature, salinity, pH, dissolved oxygen, as well as the number of phytoplankton and zooplankton species. Additionally, it describes the temporal distribution of chlorophyll-a in the mixed zone and the zooplankton in the waters of the Dampier Strait Waigeo and the Southeast Misool.

Material and Methods

This study began with a literature search and interviews with various local communities, such as fishermen and dive tour guides, to obtain seasonality information and locate manta ray hotspots. Based on the garnered information, the sampling location was determined and it coincides with the southeast monsoon season, which spans from June to October. There were 5 sampling locations identified, namely Manta Sandy (MS), Manta Reef (MR), Hool Gam (HG), Arborek West (AB), and Yefnabi Kecil (YK). See Figure 1. Furthermore, in Southeast Misool, they are 7, including Magic Mountain (MM), Eagle Nest (EN), Boowindow (Bwn), Tj. Warakaretek(TjW), Boowest (Bws), Kanem (K), and Tanjung Kerikil (TjK), as shown in Figure 1. These places were chosen over a distance of 183.7 km between the Dampier Strait Waigoe and Southeast Misool.

Collection of data on environmental conditions

Environmental parameters were measured at each manta ray sighting hotspot. The data collected include sea surface temperature, pH, dissolved oxygen, and observation of tidal conditions. Measurement of several environmental parameters using the AMTAST PC900 tool is a measuring instrument that can measure seven parameters: pH, mV, conductivity, TDS, salinity, resistivity, DO, and temperature in water solutions. This tool has a high level of accuracy and can produce accurate results. The chlorophyll-a data used were secondary data from the Marine Copernicus download. Chlorophyll-a in Raja Ampat waters was downloaded based on the western, eastern, and transitional seasons with depths of 0.4 meters, 5, 10, and 15 m. Environmental parameters were analyzed descriptively in the form of tabulations, while the chlorophyll-a data were analyzed using the kriging method on ArcGIS.

Data collection, identification, and percentage of zooplankton

Zooplankton data were collected at each hotspot where manta rays appeared. Sampling was conducted during the day from 08.00 to 10.00 local time using a 25 cm plankton net pulled from 10 m and 5 m to the surface. The water sample was concentrated to 10 ml and preserved using 4% Lugol-Iodine (Cahya *et al.*, 2021). Plankton was identified in the Aquatic Resources Laboratory, Faculty of Fisheries and Marine Sciences, University of Papua, Manokwari, West Papua. The process was performed conventionally using a microscope, with pictures of plankton being captured to facilitate the identification of morphological characteristics based on books (Thomas, 1997) and (Yuliana and Mutmainnah, 2021). Subsequently, the species name obtained was matched back online at https://marinespecies.org/.

Manta ray sighting data collection

Direct surveys were conducted to collect data on manta ray sightings and information from local tourism divers and fishermen in southeast Misool. Data on hotspots were collected in the Dampier Strait, Yefnabi Kecil, and Southeats Misool from June to September 2021. Other sighting information was obtained from local divers, tourists, and fishermen. Manta ray data collection during the observation was based on a simple assessment by divers.

Generalized Additive Models (GAMs)

The study utilized generalized additive models (GAMs) as an analytical tool to understand the relationship between environmental parameters such as salinity, temperature, wind velocity, degree of acidity/pH, dissolved oxygen, chlorophyll-a, and abundance of zooplankton on stingray sightings (Table 1.). The analysis was conducted using R version 4.3.1 (2023-06-16 urct). To determine the best model, a total of eight model tests were carried out using both the General Linear Model (GLM) and the GAM, based on Akaike's Information Criterion (AIC) function. The value of degrees of freedom (df) was 4 or 5, which was considered essential for explaining the relationship mechanism of the assumptions (Hastie and Tibshirani, 1986).

Result and Discussion

Concentration and distribution of chlorophyll-a.

Chlorophyll-a concentrations in this study were based on the descriptive values of the west, east, and transitional seasons. In 2021 (Figure 3.), the highest average chlorophyll-a concentration was observed in the eastern season at 0.505 $Mg.m^{-3}$ and was within

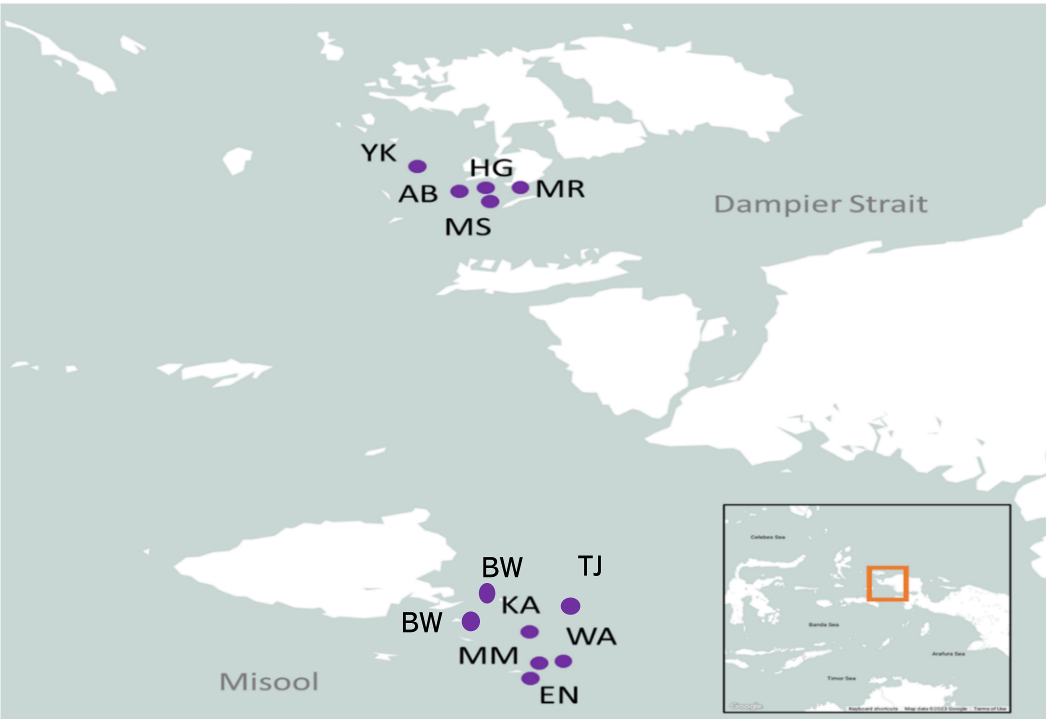

Figure 1. Manta rays Hotspot in Dampier Strait and Southeast Misool MPA Raja Ampat.

the range of 1.030-1.064 Mg.m^{-3}. The distribution at the peak of the western season was sporadic. At depths of 0.4 and 5 m, chlorophyll-a tended to be collected on the east side of Salawati Island and the north-northwest Raja Ampat waters, with a range of 0.28-0.33 mg/m^{-3}. At the peak of the west-to-east season transition, the distribution pattern is from north to east, with a range of 0.16-0.97 Mg.m^{-3}. During the eastern season and transition 2, the distribution pattern of chlorophyll-a tended to be consistent. Chlorophyll-a was collected from the west and north sides, with concentrations ranging from 0.62 to 1.09 mg-m3. During this season, Raja Ampat's inner waters had relatively low chlorophyll-a, especially in the Misool, Batanta, Salawati, and Kofiau Island areas.

The distribution of chlorophyll-a in Raja Ampat waters varies throughout the year and tends to form the same pattern. From 2019 to 2021, its spatial distribution at each peak season shows a low value during the western season and transition I (December-May), and increases at the east season and transition II (June-November). This is consistent with previous studies such as (Siadari *et al*., 2016) who reported relatively low chlorophyll-a in Papua waters during the western season and transition 1. An increase was observed in the east season and transition 2. Furthermore, (Massa and Radjawane, 2014) reported a low chlorophyll-a value in the west monsoon and transition 1 relative to the east monsoon and transition 2. Following this study, (Clinton *et al*., 2022) stated that the concentration in the Bali Strait was relatively low in the west season until transition 1 and seemed to increase in the east season and transition.

The movement of the north-western monsoon winds with warm sea surface temperatures marks the low chlorophyll-a concentration in the west and transition seasons. (Ulath, 2012) stated that the relatively warm SST during this season, due to low wind speed, reduced heat transfer from water bodies to the air. Indications of an increase in the upwelling phenomenon from the Halmahera eddies on the north side cause southwestern monsoon winds to move the Equatorial Current from the northern coast of Papua. It carries a mass of warm water and spreads throughout the Papuan, including on the eastern side of Raja Ampat (Sidabutar *et al*., 2014), which triggers the low value of chlorophyll-a in the water column. In addition to the current mechanism, the input of nutrients from the large rivers of South Sorong, Sorong Regency, and the mainland of Papua, which are adjacent to Raja Ampat waters, has been a factor in increasing the concentration of chlorophyll-a.

The east and transition seasons are marked by a decrease in sea surface temperature caused by south-easterly winds blowing in Raja Ampat waters. In contrast to the western monsoon, the concentration of chlorophyll-a is relatively high and can be seen on the west side of Raja Ampat waters. This finding is coherent (Ulath, 2012) that the possibility of an upwelling process due to the strengthening of the southeast wind, which moves the surface mass to the west side. As a result, the water surface is filled by its mass that is lifted from the column (Ekman Transport). This situation can be observed on the east and south of Misool Island (Ulath, 2012). According to (Ulath, 2012), indications of upwelling occurred in June, along with the strengthening of the southeast monsoon winds, which encouraged the intensity, where this phenomenon became higher between July and September. In the east season and transition 2, the average SST is relatively colder in the north of Raja Ampat, such as the north, south, and east of Waigeo Island, which triggers an increase in the higher chlorophyll-a value (Tangke *et al*., 2015; Ulath, 2012).

Table 1. Predictor data and responses in determining the relationship and influence of manta ray sightings

Variable	Parameter	Description	Data type	Unit	Average (±SD)
Response data Sightings of manta rays	Manta rays sightings	The number of individuals found in each observation at nine hotspots	Continuous	-	-
Predictor data	Salinity	Field measurement	Continuous	ppm	30.75 (1.32)
	temperature	Field measurement	Continuous	^{0}C	29.57 (1.09)
	wind velocity	Field measurement	Continuous	m.s^{-1}	4.8 (1.35)
	degree of acidity/pH,	Field measurement	Continuous	-	7.98 (0.08)
	dissolved oxygen	Field measurement	Continuous	mg.L^{-1}	7.92 (0.57)
	Chlorophyll-a	Re-analysis marine Copernicus	Continuous		0.875 (0.82)
	Depth	Field measurements when sampling are at 5 and 10 meters	Continuous	m	7.5 (2.55)
	An abundance of zooplankton	Field measurement	Continuous	Individu.type^{-1}.ml^{-1}	2.83 (3.51)

Seasonal patterns affect the distribution of chlorophyll-a horizontally and vertically, as shown in Figure 3. According to Uneputty *et al*. (2022), chlorophyll-a is a vital component supported by phytoplankton which is a food source for fish in water. In the food chain system in marine waters, phytoplankton acts as a producer and is a primary factor in the abundance of zooplankton as a first-level consumer. As a result, its distribution in the waters is more even than zooplankton. This is a result of the productivity of phytoplankton which is photoactive or close to light (Nybakken, 1992). Meanwhile, zooplankton, which moves vertically, follows the development of phytoplankton and can stay away from light. The vertical pattern generally occurs when zooplankton is discovered near the sea surface and bottom layer at night and towards morning, respectively (Mariyati *et al*., 2020; Moniharapon *et al*., 2014). During the day or when the intensity of sunlight is maximum, it remains at the deepest depths (Mariyati *et al*., 2020). Its horizontal and vertical patterns encourage the biomass of pelagic fish such as *Sardinella lemuru* (Susilo *et al*., 2021) and the appearance of elasmobranch planktivores in the waters (Rohner *et al*., 2013). This is because zooplankton is the main prey (Anderson *et al*., 2011; Rohner *et al*., 2013; Wall *et al*., 2013)

The occurrence of manta rays in Raja Ampat waters is observed to be consistent throughout the year with a fluctuating peak season. According to a report by (Setyawan *et al*., 2018), upwelling and primary productivity occurs on the western side of Waigeo during the southeast monsoon season, which lasts from May to October. The upwelling process is believed to provide nutrients to certain aggregation hotspots located close to the western side of Waigeo, hence, increasing the productivity of phytoplankton and zooplankton in the surrounding waters. This increased productivity, in turn, encourages the emergence of manta rays.

Types and percentage *of zooplankton in Manta Rays hotspots*

The percentage of phytoplankton in the Dampier Strait is higher, while zooplankton is relatively high in Southeast Misool. At a depth of 5 meters, the number of individuals was more significant at 69.7% in the Dampier Strait, compared to 51.38% in Southeast Misool. At a depth of 10 meters, it was 51.38% which was higher than southern Misool. Finally, the highest percentage of zooplankton was observed at a depth of 10 meters in Southeast Misool.

During sampling, about 14 species of zooplankton were discovered. The most dominant species were Calanoid spp 35%, *Oithona nana* 13%, *Acartia clausi* 11%, *Calanus helgoladicus 9,1%* and *Oithona brevicornis* 9%. The other species have low percentages, which are below 5%, as presented in Figure 3. The types of zooplankton observed in both hotspots were primarily composed of *Calanoid spp, Oithona nana, Acartia clausia, Calanus helgoladicus*, and *Oithona brevicornis*.

Figure 3 showed the types of zooplankton discovered at the sampling location, which belong to the demersal group that typically inhabited reef areas. (Alldredge and King, 1977) reported that demersal zooplankton is a reef community consisting of *Mysids, Gammarids, Ostracods, Isopods, Harpaticoids, Calanoids, Cyclopods, Decapods larvae*, and *Polycaeta*. It can maintain its position within the reef area and increase biomass concentration by wind, and tidal currents.

The combination of wind and tidal factors modulate zooplankton to retain biomass in one position and location based on habitat characteristics. Coherent with (Thovyan *et al*., 2020), high abundances of calanoid copepods were found at all hotspots in the Dampier Straits between the seasons of March and July. (Armstrong *et al*., 2021) discovered a zooplankton copepod calanoid dominant in Hanurafa Bay of the *Undunula vulgaris* type (Bennett *et al*., 2017) reported that copepod calanoids were the most abundant prey found in the stomachs of reef manta rays in a hotspot on Australia's Great Barrier Reef, out numbering *Cestoda*, *Cirripedia*, and *Sagittoidea*. These dominant zooplankton types found in the Dampier Strait and Southeast Misool have also been identified in several other reef manta ray hotspots, including the Maldives' Hanifaru Bay and Australia's Great Barrier Reef, as well as in the hulls of several mobulids, including the oceanic manta rays (Rohner *et al*., 2017).

Sightings of Manta Rays at Dampier Strait and Southeast Misool hotspots

The number of manta rays sightings during the survey varied across study sites, At the Dampier Strait and Southeast Misool locations, manta rays were only discovered at 9 locations during field sampling, with low numbers and a lack of peak aggregation. It appeared at the MS cleaning station in the afternoon during high tide conditions in depth 7-12 m. Furthermore, in YK, sightings of this species were in large numbers and at high tide. Manta rays were observed in low numbers at all locations in southeast Misool. At MM, a cleaning station, 3 of the species were discovered in the morning. Furthermore, about 8 were seen in the Eagle Nest, and 12 in the southwest EN. K discovered 2, while Boowindow and Boowest, had 2 each. All sightings of manta rays occurred in the morning except at TjK and Boowest,

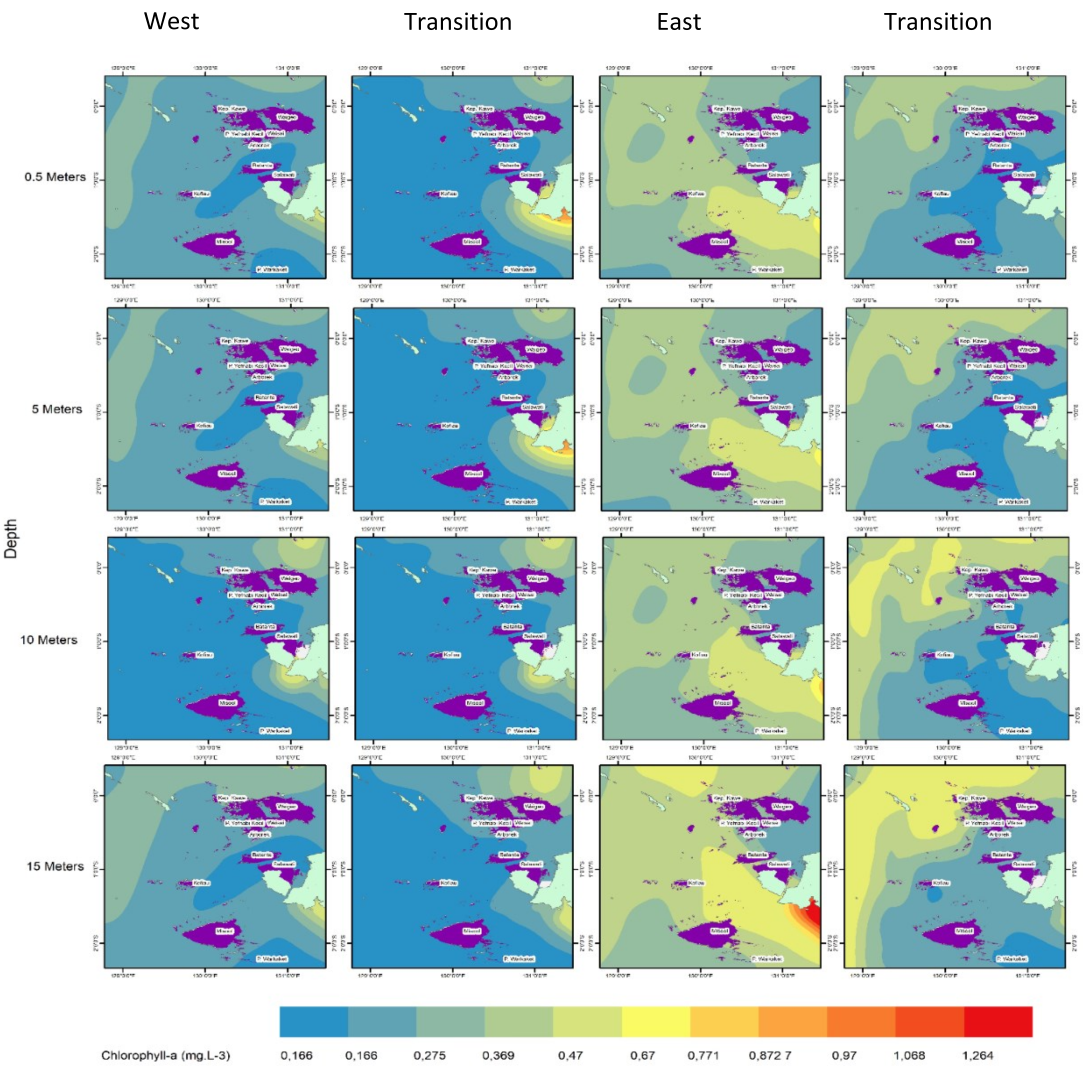

Figure 2. Distribution of chlorophyll-a in the Raja Ampat Coastal in the 2021 based on depth

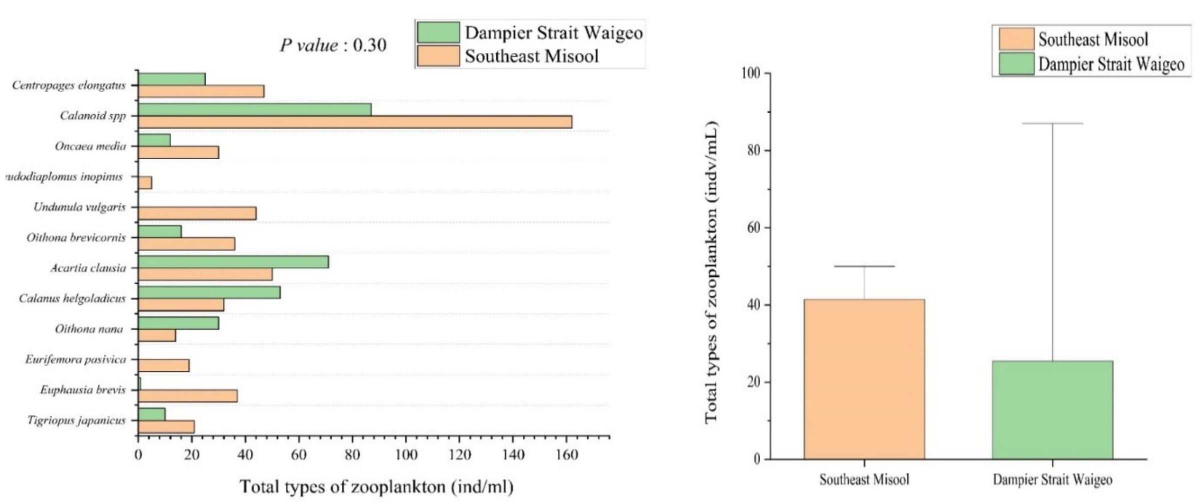

Figure 3. Total types of zooplankton in the Dampier Straits Waigeo and Southeast Misool

which took place in the afternoon at high tide. Data on the sightings were also obtained from local divers in the Dampier Strait and Pam Island.

Parameters of the coastal environment were measured to ensure the existing conditions of the waters during sampling. The average salinity in the Dampier Strait and YK was discovered to be 31.60 ppm, while in Southeast Misool, it was 30.60 ppm. The sea surface temperature at these locations was only 29.542ºC, while in southern Misool, it was 28.75ºC. The degree of acidity (pH) in the Dampier Strait and Southeast Misool, were 7.84 and 8.03, respectively. The dissolved oxygen in the Dampier Strait and YK is 7.32 mg.L^{-1} and 8.5 mg.L, respectively. These environmental data confirm that the water quality standards meet the requirements for the survival of marine organisms. The analysis begins with a linear model (GLM), which employs environmental parameters such as temperature, wind velocity, pH, and dissolved oxygen, as predictors of the appearance of manta rays in response. The result of this model was an R-sq. value of 0.229, indicating that 29.6% of the deviation was explained. From this model, the most significant predictor parameters were science (*P*= 0.0084; Figure 5.) and wind speed (*P*= 0.0038). It was refined by adding zooplankton abundance with the result of R-sq being 0.821, indicating that 86% of the deviation was explained.

The addition of this predictor variable to the linear model strengthened the significance of each predictor variable for the appearance of manta rays. In tests of the relationship of environmental factors to manta ray occurrence, we tested eight models using GAMs. The first model found no correlation between wind speed, surface salinity and manta ray occurrence. This can be seen from the relatively large AIC value of 126.92. Zooplankton abundance, salinity gradient, and wind speed on manta ray occurrence in the second model resulted in an AIC value of 94.23. The third, fourth, and fifth models produced AICs of 126.81, 126.63, and 128.83. The AIC of the sixth model was 92.51, which was lower than the seventh and eighth models of 92.85 and 92.78. Overall, the sixth model was the best model that could explain 69.98% of the variance in environmental factors on manta ray occurrence Further testing with GAMs is a smoothing function without zooplankton as a predictor, which resulted in an R-sq of 0.235, the deviation explained 29.8%. The addition of zooplankton variables obtained an R-sq. 0.84, and a deviation explained by 89.1%. Statistically, From, eigh models, shows the value of the model test from the analysis. Model 6 is considered the best for explaining the mechanism of the relationship between the predictor and the response variable.

Nine sampling locations consisting of cleaning stations and feeding habitats are detailed in Table 4, all of which exhibited low visibility in the hotspots of the Dampier Straits and Southeast Misool. The inappropriate sampling time was one of the reasons for not finding manta ray peak aggregation. It was also reported by one of the tour divers in Arborek that high numbers of sightings around MS, MR, and Manta Ridge take place between November and February. The trend data of reef manta rays presented by (Setyawan *et al*., 2018) and oceanic manta (Beale *et al*., 2019) showed that the sampling time is at a different peak. According to information gathered from local fishermen and tourist divers in southeast Misool, manta rays aggregations generally occur between August and November, as well as in January. However, sightings of manta rays were often observed at different times. This is because changes in the time of appearance are likely to occur with the assumption that local movements are relatively dominant compared to those on a wide scale.

The relationship of environmental parameters to the appearance of manta rays

The relationship between environmental parameters and the sightings of manta rays is described in the exponential model of GAMs, as shown in Figure 5. Zooplankton abundance, salinity, temperature, degree of acidity, and wind speed are considered very significant predictors. This relationship is strengthened by the value of R-sq at 0.837, indicating that the Deviance is explained by 87.9%.

Zooplankton abundance in Southeast Misool is relatively high and distributed in almost all sampling locations. Among the specific locations, *Calanoid* sp*., Oithona nana,* and *Acartia clausia* dominate at Eagle Nest, Kanem, and Southwest eagle nest, respectively. However, the dominant specie at Magic Mountain is *Euphausia brevis*, while Tj Kerikil, Bowindow, and Boowest are dominated by *Undinula vulgaris*. *Eurifemora pasifica* and *Oithona nana* dominated Yefnabi Kecil with the highest zooplankton abundance. Manta sandy and West Aborek are dominated by *Calanus helgoladicus* and *Acartia clausia*. The results of this study are consistent with those in the critical habitat of manta rays at Hanifaru Bay, where *Calanoid* ((Armstrong *et al*., 2021), *Mysid, Euphasiae*, and *Calanoid* spp are discovered on the oceanic manta ray's aggregation in Revillagigedo Islands ((Stewart *et al*., 2016). Additionally, *Euphassia diomediaeter* was dominant in the hull of 4 mobulids, including oceanic manta rays netted in the mesopelagic layer (Rohner *et al*., 2017). Bessey *et al*. (2019) reported that *Euphausia* is the main prey besides those of the fish group.

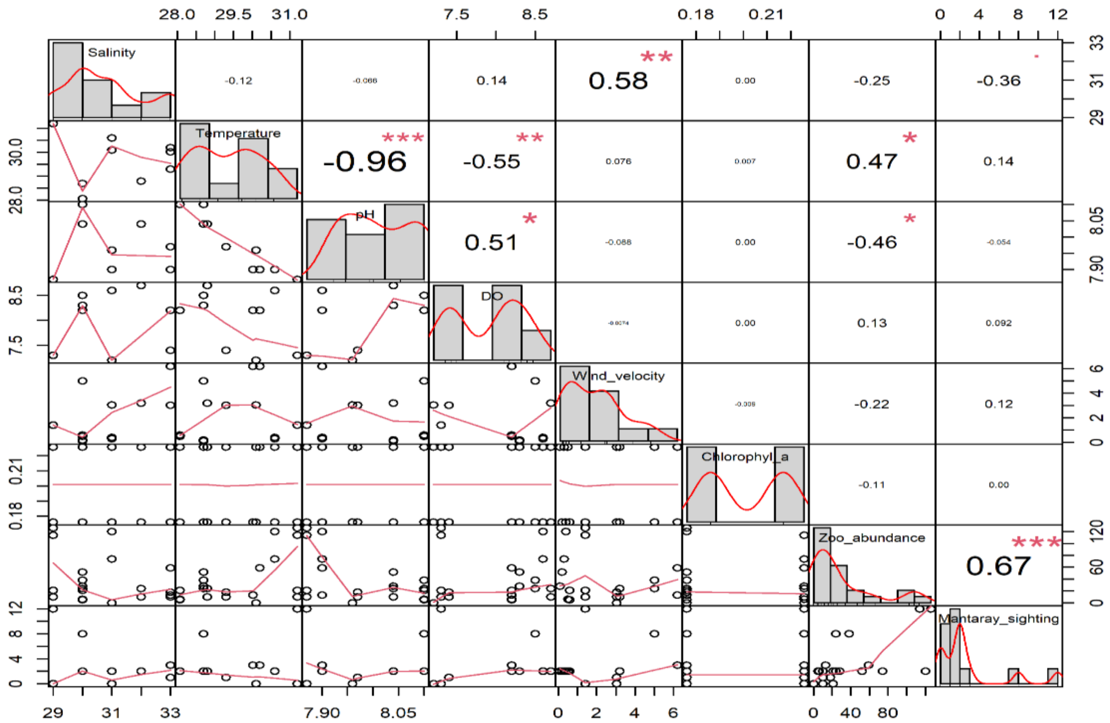

Figure 5. Scatter plot matrix depicting the bivariate relationships among potential explanatory variables between environmental variables on sightings of manta rays

This result further confirms that the zooplankton in Raja Ampat waters is likely part of the demersal group localized to the reef area. The similarity of zooplankton found in this study indicates that manta rays are very adaptive and able to adjust to the availability of accessible prey items in coastal areas. (Couturier *et al*., 2013) stated that the feeding behavior of reef manta rays can adjust its strategy according to the distribution of zooplankton. During the study, manta ray visits occurred in the morning from 07.30 to 10.00 in high tide conditions. In YK, they were seen accessing the surface of the waters, while in Southeast Misool, they were more dominant at the bottom of the waters in all hotspots. The model in this study does not have time and tides due to the short observation period. However, it is consistent with the study Rohner *et al*. (2013) and Ahsin *et al*. (2022) that there is a temporal and tidal relationship to the sightings of manta rays.

Conclusion

A significant relationship was discovered between the number of environmental parameters such as salinity, temperature, pH, dissolved oxygen, wind speed, chlorophyll-a, and plankton on manta ray sightings at hotspots in Raja Ampat. The results of this study showed that the highest chlorophyll-a concentration was observed during the east-west transitional season, with an average of 0.37 mg-m^3 and values ranging from 0.17 to 0.91 mg-m^3. Zooplankton species were dominated by *Calanoid spp, Oithona nana, Acartia clausia*, *Calanus helgoladicus*, and *Oithona brevicornis*, which are known as a driver of the presence of manta rays in these hotspots.

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